Predicting Phenology of *Vicia faba*: Parameter Estimation with CROPGRO-fababean Model Using Multiple Sowing Date Experiments

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Crop models have become valuable tools for designing efficient cropping systems, particularly once model reliability is documented for a given environment. For this use, the timing of crop phenology has to be accurately simulated to predict life cycle and the correct allocation of assimilates to yield components. The CROPGRO-Fababean model was developed based on adaptation of the generic CROPGRO legume model to simulate faba bean grown in Cordoba, Spain (Boote et al., 2002) but the model has not been tested extensively in other environments. Therefore, the model needs to be tested for additional environments, and may need to be modified to improve its reliability under a wide range of field conditions. For the initial model version, phase durations were calibrated against field data collected at Córdoba; however, the cardinal temperatures that affect phenology were derived from the literature. Because our goal was to use these parameters to make reliable predictions in new field environments, we propose that the best way to solve the coefficients is through a calibration process based on field data obtained under varying daily and seasonal temperature and daylength, similar to the method used successfully to calibrate the SOYGRO model phenology.

The objective of this work was to determine quantitatively the effects of temperature and daylength on rate of vegetative node expression, time to flowering, time to beginning pod, time to beginning seed, and time to physiological maturity with the ultimate goal of making the CROPGRO-Faba bean model more reliable over a wide range of sowing date environments.

Methodology

In order to obtain a data base of faba bean phenology progression under a wide range of temperatures and daylength during the crop growth cycle, three years of experiments with cv. Alameda and multiple sowing dates under non limiting conditions were implemented. The first two years of sowing date experiments were used for parameter calibration, while the third year was used to validate the calibration process.The study was carried out over a period of three agricultural seasons (October 2004 to August 2007) in an experimental field of the Escola Politécnica Superior (EPS) of the University of Santiago de Compostela (USC), located in Lugo (43º04’ N; 7º30’ W; altitude 480 m).

Because we wanted to develop coefficients that would be useful for improving the CROPGRO-Faba bean model, we used the model itself as a tool for optimizing cardinal temperature and daylength coefficients affecting vegetative and reproductive processes. The optimization algorithm used a simulated annealing method (Goffe et al., 1994), which program was linked with the CROPGRO program, where the two executables alternately share files. The CROPGRO program outputs simulated node number on given day of year or outputs the simulated flowering date or other reproductive phenological event, and these values are then used by the optimization program to calculate sum of squares from simulated versus observed values.

Results

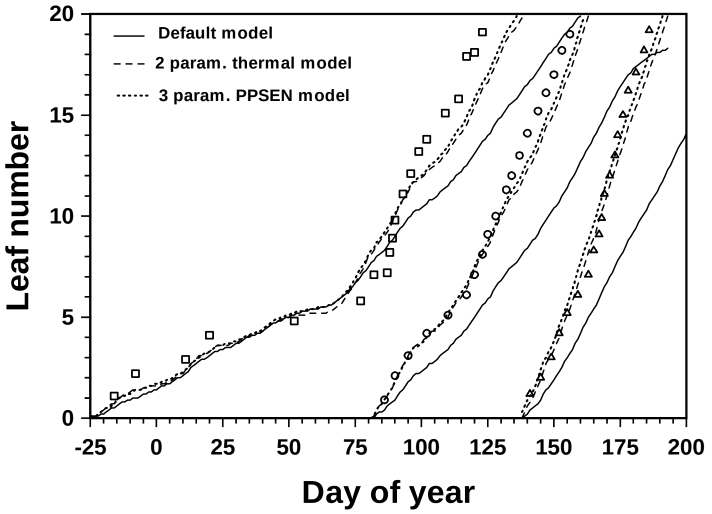

Fig. 1. Predicted and observed values of leaf appearance for three sowing dates of the first experiment (November 5 2004, February 17 2005 and May 5 2005). Default model: Tb = 0ºC; Topt1 = 27ºC; Topt2 = 30ºC; Tx = 45ºC; TRIFOL = 0.33 node/PTD. 2 param. Thermal model (calibrated TRIFOL and Tb): Tb = 3.9ºC; Topt1 = 23ºC (fixed); TRIFOL = 0.516 node/PTD. 3 param. PPSEN model (calibrated with daylength effect): Tb = 2.2ºC; Topt1 = 23ºC (fixed); TRIFOL = 0.516 node/PTD; CLDL = 24 h (fixed); PPSEN = -0.0426 (1/h)

The original model parameters need some adjustments to allow good predictions of leaf appearance rate and main phenological events under wide environmental conditions.This was confirmed by the validation process. Leaf appearance rate predictions improved considerably with higher Tb, but there was minor effect of daylength. Daylength was very clearly needed for flowering date prediction but later phase durations after flowering did not require daylengh effect.

Conclusions

The simulated annealing program coupled with COGRO-Faba bean and field collected data under a widely variable environment has proved to be an appropriate method to establish the CROPGRO-Faba bean coefficients needed to predict correctly crop phenology.

References

Boote K.J. et al. 2002. Adapting the CROPGRO legume model to simulate growth of faba bean. Agron. J, 94:743-756.

Goffe, W.L. et al. 1994. Global optimization of statistical functions with simulated annealing. Journal of Econometrics 60, 65-99.